Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**
4. TITLE AND SUBTITLE **Project management of an imaging optical interferometer**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **New Mexico Institute of Mining and Technology,Magdalena Ridge Observatory,801 Leroy Place,Socorro,NM,87801**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**		**13**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Project management of an imaging optical interferometer

E.J. Bakker*, M.J. Creech-Eakman
Magdalena Ridge Observatory, New Mexico Tech, 801 Leroy Place, Socorro, NM 87801, USA

ABSTRACT

The Magdalena Ridge Observatory Interferometer (MROI) is part of a new observatory dedicated to astronomical research. It is a 6 element optical interferometer currently in its construction phase, with a planned phase B of 10 elements. The observatory is located within 32 km from the centre of the Very Large Array (VLA) at an altitude of approximately 3230 meters. The design is optimized for faint source imaging. This makes it one of the most advanced high spatial resolution optical instruments available to the scientific community. With a staffing of up to 20 scientists and engineers, and a large fraction of the telescopes, buildings, and delay lines outsourced to industry and consortium partners, it aims for an aggressive schedule to have first fringe with 6 telescopes in late 2009. A project this size in budget, tight milestones and deadlines, requires professional management. In this paper we address the basic principles that are followed in the project management approach. We describe a generic approach and at some instances the implementation chosen at MROI.

Keywords: project management, astronomy, universities, ground-based observatory

1. INTRODUCTION

Projects in a high-tech innovative research and development environment like a university, a research institution or organization have many characteristics in common. The most important aspects of such projects are:

1. The scientists and engineers involved are highly trained, independent thinkers, and general do not perform well under a strong hierarchical structure.
2. Creative thinking and problem solving can lead to large cost savings for the overall project.
3. Although the final objective is specified, the route to realization cannot be overseen in the early phase of the project. The complexity is too overwhelming and the number of uncertainties is very large.

Given these fundamental characteristics there are a few generic techniques and tools which can significantly increase the efficiency and quality of the project [1]. These tools, together with best practice on project management, will be discussed in this paper.

2. STRUCTURING A PROJECT

The basic structure and the required resources for a project can be described in two separate documents.

Definition: project
A project has a starting date, a finish date, a limited budget, and deliverables. It is a self-contained set of activities with its own management structure and interfaces.

* ebakker@mro.nmt.edu; phone 505-835-6648; www.mro.nmt.edu

The management plan describes the decision making structure within a project, the communication channels etc. A project plan describes the deliverables; the resources needed and sets a schedule with milestones and deadlines.

The first step in almost any project is to define the objective. Examples are to build a new optical interferometer or bring a new satellite into space. This can be a very simple description for a huge project. Starting from this very simple description the complexity of the project cannot always be overseen. A project plan has the aim to structure the activities in deliverables, services etc. Hence after the objective has been set, a project plan is one of the first activities to get structured. Once sub-activities has been identified, institutional partners can be identified and the interface between people can be further structured through a management plan.

3. PROJECT PLAN

The project plan describes in detail how the objective of the project can be accomplished by splitting it up in smaller segments. In general it follows a timeline, starting with what is needed for the early phases, then describing sequential what must be done in the following phases. A project plan should be as quantitative as possible. It should be very specific about the deliverables for each phase and the individuals assigned to the different tasks. Each project plan has some standard ingredients, which are:

- Scope of the project
- List of deliverables
- Phasing
- Milestones and dead-lines
- Work breakdown structure
- Resources
- Budget

Scope of project
Define the final deliverable as accurately as possible. List the boundary conditions and possible explain how the product will be used by the customer. The customer can be an astronomer, but can also be an institution.

Deliverables
There are a few methods to monitor progress of a project. The best method is through the presentation of something which can be demonstrated and there is a quantitative assessment possible to determine if the deliverable is according to specifications. For example a piece of equipment, a next version of a software package, a capability of something. The only progress which really counts is, of course, the delivery of the final product.

Phasing
Phasing in an astronomical technology project follows traditionally a sequence of reviews. The sequence is setting the requirements, making the design (conceptual design, preliminary design, critical design, and the final design), and developing the hard or software (purchase, assembly, subsystem integration). At each step the appropriate documents need to be compiled. Once a sub-system has been tested it is integrated in a larger system.

Milestones and deadlines
To mark the beginning and intermediate steps of a process, milestones and deadlines are identified. A common way to visualize and plan a project is through the compilation of a GANTT chart (Figure 1). It allows to quickly understanding the sequence of events in a project, how these relate to each other, and when they are due.

> **Definition: milestone**
> Intermediate steps towards the production of a deliverable. It marks the end of a phase through a verifiable process. The milestone has been passed if certain pre-set criteria are passed. A milestone refers to a state of the deliverable.

> **Definition: deadline**
> Point in time at which a certain performance has been met. A deadline refers to a certain date.

Definition: GANTT chart
A GANTT chart is a tabular and graphical presentation of a schedule which plots the tasks, people responsible for these tasks, a timeline, resources and associated budget. The chart is named after Henry L. Gantt (1861-1919).

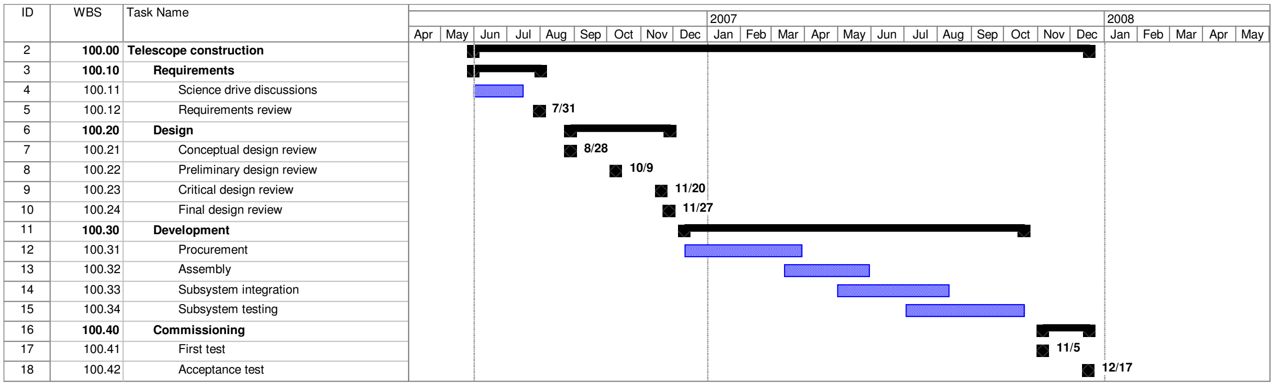

Figure 1: generic GANTT chart.

Work breakdown structure
The work breakdown structure aims to splitting up the overall project in smaller units. These smaller units are called work packages. Each work package contains a set of tasks and a deliverable. Each unit should be largely self contained and have a well-defined functionality (e.g. advisory task, skills set) or produce a deliverable. In most cases the deliverable of a work package is a required input to another work package.

Definition: work breakdown structure
Work breakdown structure (WBS) splits the project in smaller segments to monitor progress, plan ahead, and assess resources needed and used.

Resources
Once the deliverable has been sufficiently specified, and milestones and deadlines set, the remaining question is what the required resources are to complete the activities. There are many different kinds of resources. In order to make an innovative product the most expensive resource is the human resource: salary for the skilled people. The second largest resource depends on how a project team is compiled. If the project team is geographically distributed the funds required for travel can be as high as 10% of the overall project cost. If the deliverable has off-the-shelf components which are expensive, the resources for procurement can be considerable. The fourth category of resource is those related to office and laboratory space.
Resources = human resources + procurement of components + expenses for travel + office facilities

Budget
The total estimated budget can now be compiled by adding the cost for the required resources.

4. MANAGEMENT PLAN

A generic project plan specifies how deliverables from a project are structured and how they are interfaced. A generic management plan specifies how people in a project relate to each other. One could regard this as a human interface document. There are a few categories of "relation that should be identified". Amongst these are:

- Decision making authority
- Responsibility and accountability
- Communication flows
- Stakeholders

Decision making authority
Decision making authority at various levels: from strategic, technical, scientific and administrative. In general decision making authority is structured through management team meetings (at the strategic level) and work group meetings (at the technical and scientific level).

Responsibilities and accountability
Responsibilities and accountability at various levels: this ranges from who is responsible for maintaining a certain subsystem and be responsible for that subsystem to function properly. At large this is structured to a proper job description for the employee that specifies his main tasks and to whom he is accountable. A line manager evaluates the performance of the employee on a regular basis and has the appropriate authority to give incentives.

Definition: line management
Line management is a term used for a position in an organization that has responsibilities which are hierarchically. A line manager makes the resources available for a project.

Responsibilities and accountabilities can be visualized through an organization chart. In Figure 2 a generic org chart for a technology project is presented. If this is a large project, these roles are filled in by separate persons. If the project is small they are shared with other projects or even outsourced through consultancy. For example a lawyer is very useful for the project if it has to deal with subcontractors, but in many cases a full time lawyer is not needed. It is more cost efficient to hire a lawyer on a case to case basis. The generic org chart (not specific for MROI) below has 18 job profiles (excluding the science board and the funding agencies). To fill all these positions and assuming a ratio of 2 to 1 for material cost versus salary, this project has a burn rate of between $6M and $8M per year. For a project with a duration of 5 years this is $30 to $40M for the complete project cost.

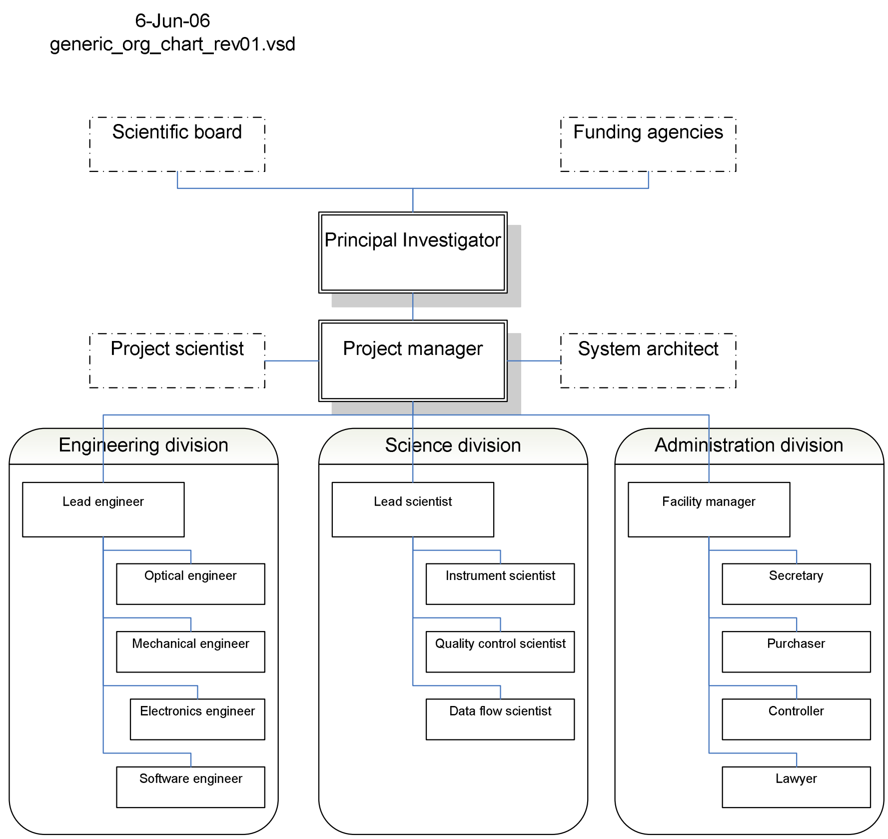

Figure 2: generic org chart for a technology project.

Definition: organization chart An organization chart (org chart) is a visual representation of the key roles within a project. It links the different players hierarchically and functionally together.

Communication flow
In complex projects the communication and information flow within the project requires serious attention. Although much of the communication on a scientific and technical level will be written down in documents, this is not always the most efficient method to spread information. Information and decisions might not have been written down yet, or the written version might be incomplete. Communication can be facilitated using various techniques. Amongst these are “staff meetings”, “work package meetings”, “individual meetings”, news letters, reporting, and informal events. To improve on the efficiency of the communication flow, the format for each meeting and activity should be identified. The different activities should have little or no overlap and the set of participants should not be identical.

Staff meeting: at a staff meeting the full staff comes together and an update is provided on progress of the different activities. Problem issues are presented and their impacts on activities are discussed. The overall purpose of a staff meeting is to spread information such that all the staff is fully aware of the activities going on beyond those in which he is involved. The staff meeting is not the platform to make decision.

Work package meeting: at a work package meeting the objective is to monitor progress, plan ahead, and make decisions on a technical level required to make progress. The number of people attending work package meetings is small and presence is limited to those who are making a contribution to the work package.

Individual meeting: individual meetings aim to coach the employee in his career development. To act as a sounding board to deal with work related issues. Discussions range from technical, personal to interpersonal.

Stakeholders
No project stands on its own as there is always a world surrounding it. There is always somebody who initiates it, and there are always parties who have either an interest that the project will succeed or fail. The stakeholders are those parties which are not part of the project team, but who are directly interested or affected by the project. Typically stakeholders include the funding agency, policy makers, competitors, partners, consumer base etc. (Figure 3).

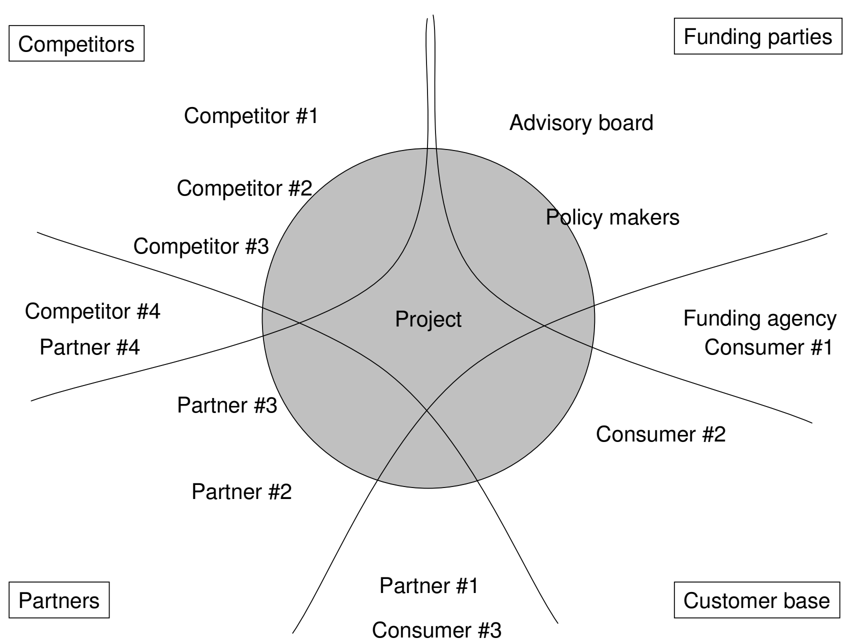

Figure 3: generic stakeholders map of a project.

Definition: stakeholder
Stakeholders of a project are institutional parties outside of the project who have an interest in the objective of the project.

Overview
Table 1 gives an overview of the different human interfaces and the tools to structure these interfaces.

Type of interface	Tools for structuring
Decision making authority	Managers
	Management teams meeting
Communication flows	Staff meeting
	Work package meeting
	Individual meeting
	News-letter
	Reporting
	Informal events
Stakeholders	News-letter
	Reporting
	Shows and exhibitions

Table 1: overview of human interfaces in a project.

5. EXECUTION OF A PROJECT

The largest impact on the efficiency of executing a project is how it is structured. This was discussed in the previous chapter and the tools for this are to write a project and a management plan. A more challenging and longer lasting task is the execution of the project. To do all the things as described in the different plans. Issues which need to be addressed during the executing of a project are amongst others:

- Planning and progress
- Budget control
- Resource control
- Quality control
- Reporting
- Risk management

Planning and progress
A process should be in place to monitor progress within each of the work packages and to plan the activities. In the previous section we discussed the different flows. Now it is time to practice these plans and to implement them.

Budget control
Budget control is of eminent importance for a project. The common way to do this is through regularly determining the cash flow and compare this with the original estimate, baseline. Depending on the dynamics of the project, this can be done on a monthly or yearly basis.

Resources control
In an innovative environment e.g. at universities it is not common practice to have a system in place that tracks for each employee on which projects he has worked during the course of a week. Nevertheless, it has a rather large added value to have an effort registration in place. The simplest technique is that each employee fills in a form at the end of each week which he lists the activities he has worked on.

Quality control
Quality control means that there are sufficient mechanisms in place to guarantee the quality of the process or deliverable.

Reporting
Reporting is a mean to monitor progress and put progress in writing. Furthermore it fulfils the role of internal and external communications since the report can be distributed to a larger group of people.

Risk management
Risk is always present in a project. Risk can be due to "single point failures" of skills of personnel (e.g. only one person has the skills if he leaves the project or turns ill, the project is delayed). Supply of sub-components can be delayed. Or critical design criteria may proof to be wrong or incomplete. Although risk can never be excluded, there is a golden rule to minimize risk. Think ahead and anticipate the unexpected.

6. FINISHING A PROJECT

The end of a project is reached if the customer has accepted the deliverable. It is important to notice that the end is not reached when the funds are depleted, but rather when the objective is reached. If the project is terminated because the funds are depleted and the deliverables have not been presented, the project has failed. Half a deliverable is in many cases not very useful and does not have the anticipated impact.

Evaluation of the project
People in projects are continuously learning. The requirements on a project are changing. In many cases people who run projects rise on the career ladder of going to large projects and getting a more responsible role within the projects. Hence it is important to learn from the projects and bring the experience gained back in the next project.

7. IMPLEMENTATION AT THE MRO INTERFEROMETER

The Magdalena Ridge Observatory Interferometer (MROI) is part of a new observatory dedicated to astronomical research [2, 3]. The interferometer is a 6 to 10 element optical interferometer currently in its construction phase. The observatory is located within 32 km from the centre of the Very Large Array (VLA), at an altitude of approximately 3230 meters. At 600 nm observing wavelength it reaches a spatial resolution of 0.4 milliarcseconds in the optical at a maximum baseline of 350 meters. The design is focused on faint source imaging. This makes it one of the most advanced high spatial resolution optical instruments available to the scientific community.

With a staffing of up to 20 scientists and engineers, and a large fraction of the telescopes, buildings, and delay lines outsourced to industry and consortium partners, it aims for an aggressive schedule to have first scientific data with 6 telescopes in late 2009. In this section we address how some of the topics addressed in the previous chapters are implemented at MROI. But before doing so we make an assessment of the objective of the project and how this relates to the internal capabilities of the project and how the project fits into the global picture. One could regard this as a market analysis.

SWOT analysis
SWOT stands for "Strength, Weakness, Opportunities, and Threats". The first two being internal to the project and the latter two are external to the project. A limited SWOT analysis for MROI is presented in Table 2.

Internal to the project	
Strength	Weakness
• Small team • Clear and simple focus • Extensive experience with interferometers • Fully funded	• Limited human resources • Small astronomer base
External to the project	
Opportunities	Threats
• Imaging optical interferometry is in demand • Fain source science is in demand • Technology roadmap needed for next generation interferometers	• Interest by mainstream astronomy • Many other instrumentation facilities are under construction or planned

Table 2: SWOT analysis for MROI.

Market analysis
For any project one should clearly identify what the objective is and how the "deliverable" will be used. In many projects the goals are simple and can be described in a few lines. However there are many ways to reach these goals and not all of them will lead to the same added value of the product to the market. For MROI the goal is to build an optical imaging interferometer. A market analysis of similar interferometers shows that there is a real added value for an optical interferometer which can do faint source imaging. Hence during all design and development steps this added value to the current set of operational observatories is a driving force.

Project structure
The complexity of the project is rather large and the project needs to be split up in smaller, self contained units. A work breakdown structure is developed which identified the subsystems of the interferometer. A first step is to classify the work package in four categories:
General activities: those activities which are not related to any subsystem, but rather deal with the interferometer or observatory as a whole.
Scientific infrastructure: infrastructural subsystems of the interferometer. They are listed in the order the light photons passing through the system. Photons first hit the telescope M1 mirror, and being relayed to the vacuum system to the optical laboratory. After the path has been delayed with the delay lines, the beams are compressed and aligned and checked for image quality. The light enters the interferometric building. Included in this category are additional laboratory space and equipment to relocate the telescopes.
Scientific instruments: these are at the core of the interferometer. The atmospheric delays are measured by the fringe tracker. The scientific instrument takes the science data.
Software: software that runs the instrument as an integrated system (interferometer control system) and offline observation preparation and data reduction software tools are in a separate category.

Work breakdown structure
Within these four categories, deliverables can be identified and linked to work packages.

A critical aspect of running projects is making people (scientists, engineers, managers etc.) accountable to their activities. To make people accountable requires certain boundary conditions to be met: amongst which are:

- The skill set of the individual needs to be well matched with a deliverables.
- The deliverables need to be well defined and be contained in parameter space.
- The individual should be able to assess the resources needed to perform his/her role.

An overview of these four categories and the work packages included per category is presented in Figure 4.

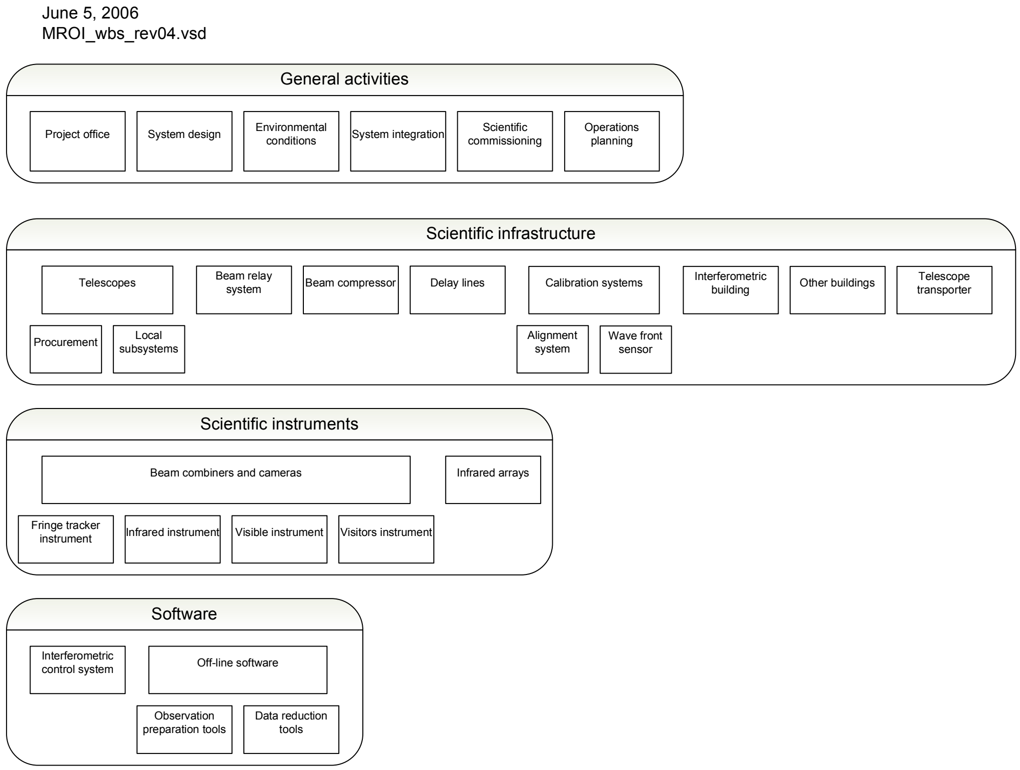

Figure 4: work breakdown structure for the MROI project.

In most cases, the work packages can be placed under the responsibility of an individual. In most cases this individual is responsible for delivering the end product.

Phasing of the project

A work package is not only confined to producing a deliverables, but also in phasing of the project. For each subsystem phases of development can be identified. In most cases: requirements, design, development, subsystem integration, testing, and documentation (Figure 5).

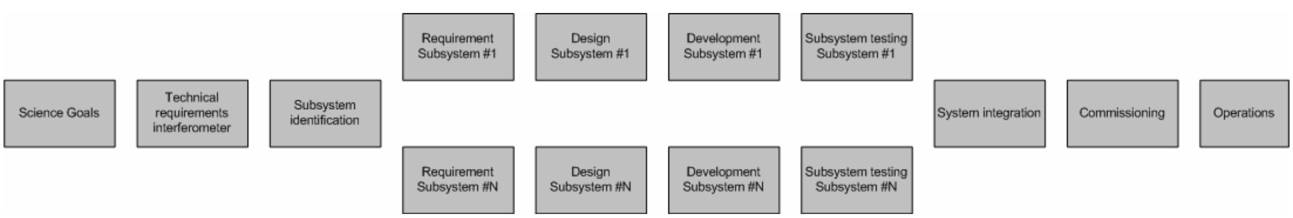

Figure 5: phasing of subsystem development at MROI.

Internal communication tools

Internal communication tools are critical for the efficient spread of information in the project. Different levels of communication are identified in the project (Figure 6).

Strategic decision making: spread of information and decision making which has long term strategic implications for the project. Examples are the science objectives of the instrument, hiring new people, collaborations and certain large procurement. This mechanism for this communication is “management team meetings”.

At the other end of the spectrum are meetings in which no decision at all is made, but which serve instead as a communication platform. This is what at MROI is defined as a staff meeting. The only purpose is to spread information about what everybody is doing and which decisions have been made.

In the middle of the spectrum are meetings in which decisions on a technical level are being made. This is referred to as work package meetings.

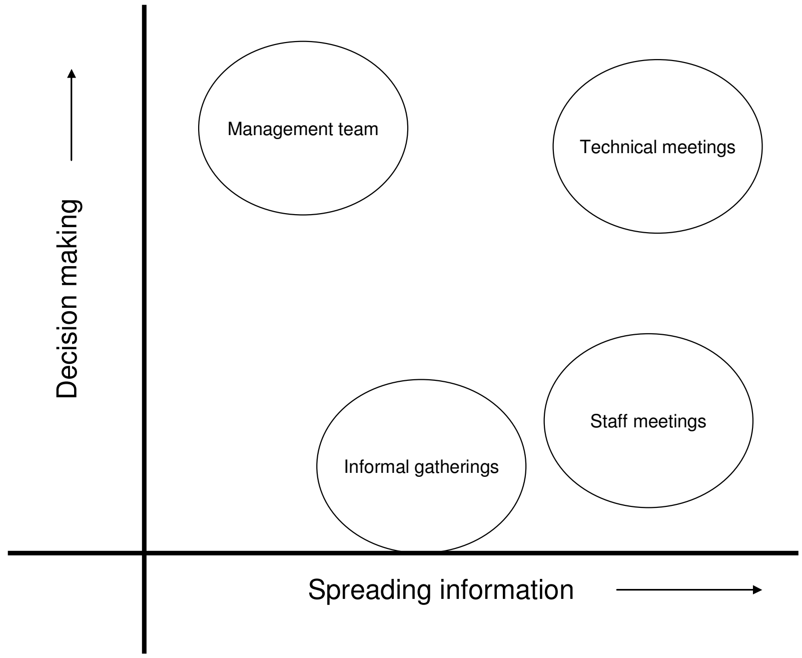

Figure 6: location of different communication tools in a “decision versus information” diagram.

Management structure
With a fast track project, setting milestones and deliverables and structuring the project that it can meet its milestones is critical. To structure a project, different roles contribute to the success of the project (Table 3).

The responsibilities of the principal investigator (PI)
- Responsibility for the overall direction of the project;
- Arbitration of any disputes that may arise within the project and, any disputes that may arise between the project and the customer;
- In carrying out these tasks the PI will consult with the PM, PS and the SA.

The responsibilities of the project manager (PM)
- Management of the day to day operations within the project, including priorities, schedules and manpower allocations of the staff;
- Responsibility for hiring staff, in consultation with the Principal Investigator (PI) and Project Scientist (PS);
- Responsibility for the budget and expenditures in consultation with the PI and PS. The PM can decide on budgetary matters to the amount of xx per occasions;
- Organization of regular meetings to facilitate communication within the project;
- Production of regular (e.g. monthly) written reports for various parties;
- To optimize internal and external communications;
- Organization of the procedures whereby long-term strategy is determined by the PI and PS;

The responsibilities of the project scientist (PS)
The project scientist has the prime responsibility to safeguard the scientific performance of the final deliverable.

The responsibilities of the system architect (SA)
The system architect has the prime responsibility to safeguard the technical performance of the final deliverable and deal with all subsystem interfaces on a system level.

The responsibilities of engineers and scientists
The engineering staff has the responsibility to use their skills and training to exercise their engineering tasks. The scientific staff has a similar role as the engineering staff, but generally operates closer to the science. An instrument scientist has the responsibility over a subsystem (e.g. fringe tracker, near-infrared instrument).

Overview

Title	Primary function
Principal investigator	Strategic direction and spokes person for project
Project manager	Day-to-day management within budget and time
Project scientist	Has a functional responsibility to safeguard the scientific performance of the project objective
System architect	Has a functional responsibility to safeguard the technical performance of the project objective and interface all the sub systems
Instrument scientist	Has the responsibility of a capability (instrument, software package etc.)
Technicians	Skilled workforce to conducts a wide range of task

Table 3: overview of different roles within the MROI project.

Organization chart
Now we have identified the different roles and responsibilities, there relation to each other can be detailed out in an organization chart. The current implementation at MRO is visualized in Figure 7 but is still under development.

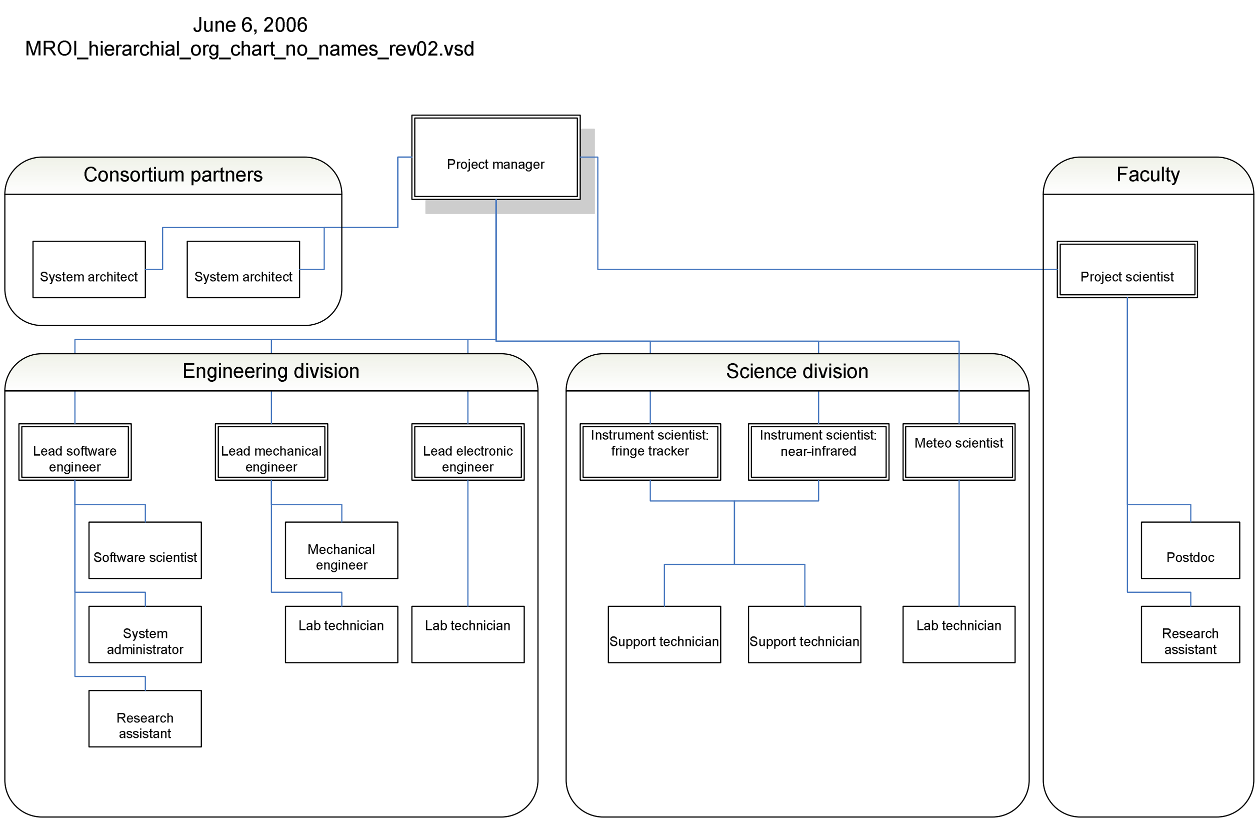

Figure 7: organization chart for MROI.

At MROI we maintain a matrix structure. MROI employees have a skill set in optics, mechanics, electronics, software, astronomy etc. This identifies the division they are hierarchically associated to. On the other hand, each of them participate in several work packages and several deliverables. For each of these work packages there is a work package leader responsible for progress and planning. This is referred to as a matrix structure.

Definition: matrix structure
In a matrix structure each individual employee has at least two supervisors. The main supervisor is a line manager which supervises and coaches the employee. The other supervisors are the work package leaders of those work packages the employee participates in.

8. CONCLUSIONS

In this paper we have described the basic building blocks for a generic project in a high-tech innovative research and development environment. How these generic blocks are implemented in a project very much depends on the size of the project and the environment in which it is embedded. This paper describes in some instances how these generic building blocks have been implemented at the Magdalena Ridge Observatory Interferometer. Projects are continuously evolving and so does the MROI project. Up to date details about MROI can be found at www.mro.nmt.edu.

REFERENCES

1. Project management institute (PMI) www.pmi.org
2. M. J. Creech-Eakman, D.F. Buscher, C.A. Haniff, V.D. Romero, "The Magdalena Ridge Observatory Interferometer: a fully optimized aperture synthesis array for imaging", *Proc. SPIE* Vol. 5491, p. 405-414, New Frontiers in Stellar Interferometry; Wesley A. Traub; Ed. (2004)
3. M. J. Creech-Eakman, E. J. Bakker, D. F. Buscher, T. A. Coleman, C. A. Haniff, C. A. Jurgenson, D. A. Klinglesmith III, C. B. Parameswariah, V. D. Romero, A. V. Shtromberg, J. S. Young, "Magdalena Ridge Observatory interferometer: status update", *Proc. SPIE* Vol. 6268, these proceedings (2006)

ACKNOWLEDGEMENTS

Magdalena Ridge Observatory (MRO) is funded by Agreement No. N00173-01-2-C902 with the Naval Research Laboratory (NRL). The MRO interferometer is hosted by New Mexico Institute of Mining and Technology (NMIMT) at Socorro, NM, USA, in collaboration with the University of Cambridge (UK).